Calibrating evolutionary tracks of young stars

F.Cusano[1],E.W.Guenther[1],M.Esposito[1],R.Mundt[2],E.Covino[3],J.M.Alcalà[3] and B.Stecklum[1]

[1]Thüringer Landessternwarte Tautenburg, Sternwarte 5, D-07778 Tautenburg, Germany, [2]Max-Planck Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany, [3]INAF-Osservatorio Astronomico di Capodimonte via Moiariello 16, I-80131 Napoli, Italy

Introduction

Up to now the masses of Pre-Main Sequence stars are only derived by comparing the location of the stars in the H-R diagram with the theoretical evolutionary tracks. However, tracks published by various groups differ considerably due to the input physics they use (treatment of the convection, initial conditions, etc). As an example, Figure 1 shows the differences existing between the most used PMS tracks (Palla & Stahler 1999, D'Antona & Mazzitelli 1997, Baraffe 1998). The aim of our work is to test and calibrate the PMS tracks determining the dynamical masses of a set of young spectroscopic binaries. In the last 8 years we carried out an optical spectroscopic survey in the southern star forming regions to find suitable (distance <150 pc, P>50 days) binaries for the VLTI. We found 15 binaries (Guenther et al. 2007). By combining spectroscopic and interferometric data we will able to get for the fist time the masses of many young stars. In this ESO semester (P79) the brightest of our object, HD113449, is beeing observed with AMBER.

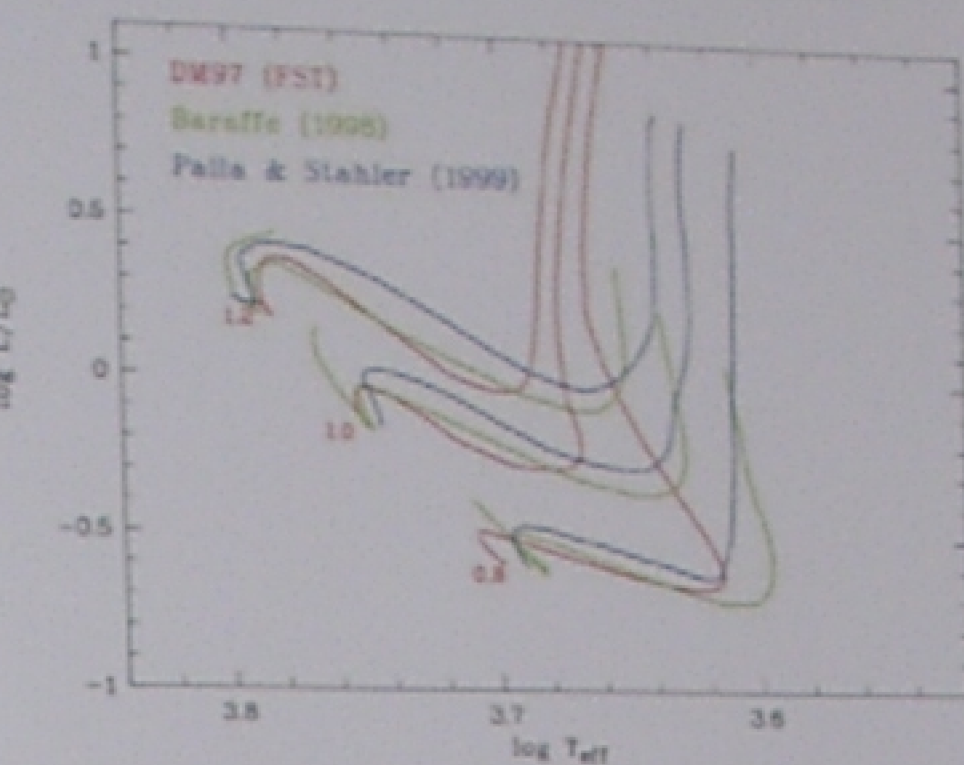

Figure 1: Evolutionary tracks for different authors.

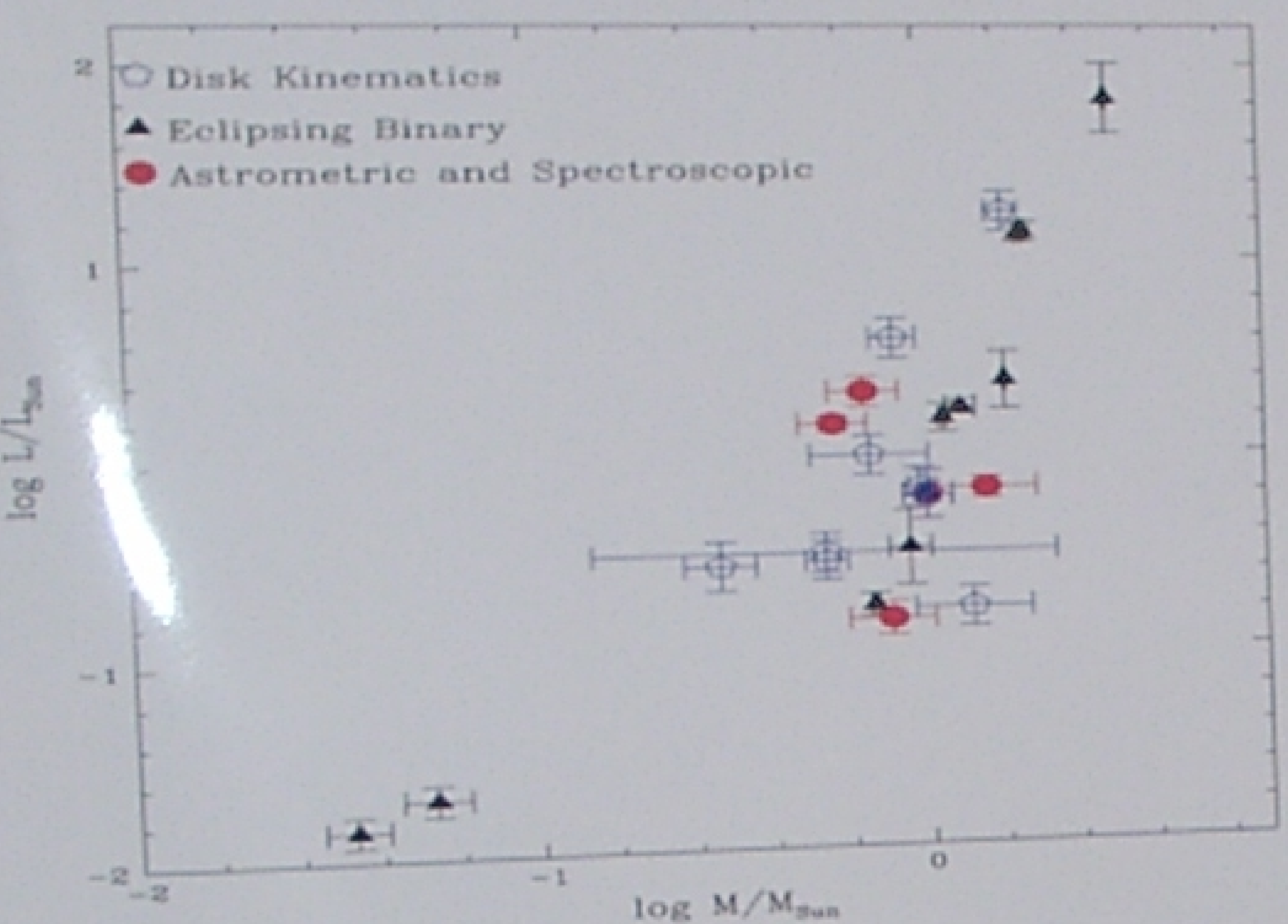

Figure 2: Mass-Luminosity relation for PMS stars.

Previous work

Up to now there are 6 known eclipsing young binary stars (Andersen et al. 1991, Casey et al. 1998, Covino et al. 2000, Popper 1987, Stassun et al.2004, 2006). By modeling the disks of PMS stars Simon et al. (2000) were able to estimate the masses of 7 additional stars. The errors in this case are larger than for eclipsing binaries.

Another method for determing the masses is to combine the relative astrometric and spectroscopic orbits of a binary system. Using the HST Fine Guidance Sensors Steffen et al (2001) derive the masses of another PMS binary. The first work with ground-based interferometry on a young binary has been done recently (Boden et al. 2005). This work is especially interesting because this object can only be explained if it is assumed that either this system has unusually low metallicity or already a radiative core at the age of 1 Myr. Figure 2 shows all the PMS stars where the masses have been determined.

Mass determination with AMBER

Our sample consists of 15 binaries stars of different spectral types (Table 1). They came out of a spectroscopical survey of about 120 PMS stars in all star forming regions of the southern sky that have a distance < 150 pc. All of them have orbital periods between 50 and 3000 days and thus can be resolved with AMBER.

The first step through the derivation of the mass is to find the spectroscopical orbital solution of the binaries, as we did for almost all of our targets. Figure 3 shows the phase-folded diagram for one of our SB2: RXJ1559.2-3814 which has an orbital period of 474 days. In the second step we need interferometry. The AMBER observables are the square visibility and the closure phase. For a resolved binary system the square visibility is:

$V^2=V_1^2+V_2^2 r^2+2V_1V_2 r\cos[(2\pi/\lambda)\mathbf{B}\cdot\mathbf{s}]$

where V_1 and V_2 are the visibility for the two stars alone, r is the brightness ratio between the primary and companion, **B** is the projected baseline vector and **s** is the angular separation vector on the plan of the sky. By fitting the square visibility as it variates with hour angle we can derive the angular separation of the two stars and from this all the orbital parameters using the Thiele-Innes method. In particular we can obtain the inclination angle of the system so that we can derive the masses of an SB system with high accuracy.

Table 1. Spectroscopic binaries with periods longer than 50 days

	region	EW Hα [Å][1]	EW LiI [Å]	spec type	m_K [mag]	RA (2000.0)	Dec (2000.0)	type	period [days]
HIP50796[2]	TWA			K5	7.660 ± 0.031	10 22 18.0	-10 32 15	SB1	?
CS Cha	Cha	−41 ± 12	0.53 ± 0.01	K4	8.199 ± 0.029	11 02 26.3	-77 33 36	SB1	2858
HD97131[3]	TWA			F2	7.697 ± 0.024	11 10 34.2	-30 27 19	ST3	134
RXJ1220.6-7539	Cha	fi	0.21 ± 0.06	K2	7.927 ± 0.024	12 20 34.4	-75 39 29	SB1	613
RXJ1524.0-3209[4]				K7	8.644 ± 0.020	15 24 03.5	-32 09 51	ST	
RXJ1534.1-3916	Lup	abs	0.21 ± 0.02	K1	8.553 ± 0.023	15 34 07.4	-39 16 18	SB1	> 1900
RXJ1559.2-3814	Lup	−1.4 ± 0.2	0.23/0.14		9.344 ± 0.019	15 59 16.1	-38 14 42	SB2	474
GSC 06209-00735	SC	0.3 ± 0.1	0.37 ± 0.01	K2	8.426 ± 0.020	16 08 14.8	-19 08 33	SB1	1961
NTTS160814-1857[5]	SC	0.7		K2	7.694 ± 0.020	16 11 09.0	-19 04 45	SB1	145
GSC 06213-00306	SC	fi	0.24/0.18		7.428 ± 0.024	16 13 18.5	-22 12 48	SB2	1489
GSC 06793-00819[6]	SC	abs	0.19/0.14/0.11	K0	7.458 ± 0.027	16 14 11.1	-23 05 36	ST3	
Haro 1-14c[7]	Oph			K3	7.784 ± 0.026	16 31 04.4	-24 04 33	SB1[1]	591
NTTS162819-2423s[3]	Oph	em	0.18 ± 0.02	G8	7.440 ± 0.024	16 31 20.0	-24 30 04	SB1	89
BS Indi[8]	Tuc	abs	0.13 ± 0.01	K0	6.574 ± 0.024	21 20 59.8	-52 28 40	SB1	1222
HD 113449				G5	5.51 ± 0.02	13 03 50	-05 09 42	SB1	215

[1] em=emission, abs=absorption fi=filled in
[2] triple system Torres et al. 2003
[3] Torres et al. 2003
[4] triple system consisting of a binary with 12 days, and one of with a period > 3000 days. (Esposito 2006)
[5] Mathieu (1994)
[6] Triple system: two components are separated by 0.″26 ±0.″03, were one of these is a binary with an orbital period of possible 16 days.
[7] Reipurth et al. 2002, eccentricity 0.617 ± 0.008, $f(m) = 0.018 \pm 0.001\,M_\odot$
[8] triple system, see Guenther et al. 2005

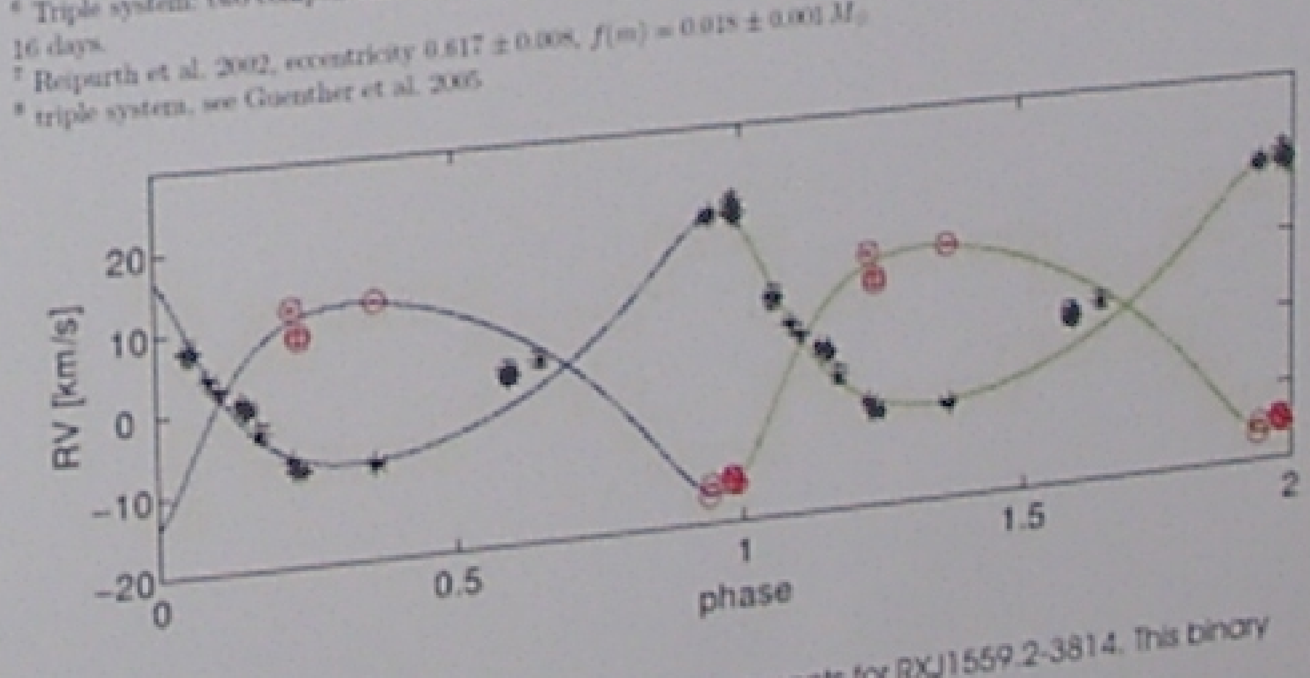

Figure 3: The phase-folded RV measurements for RXJ1559.2-3814. This binary has a period of 474 days and an eccentricty of 0.2.

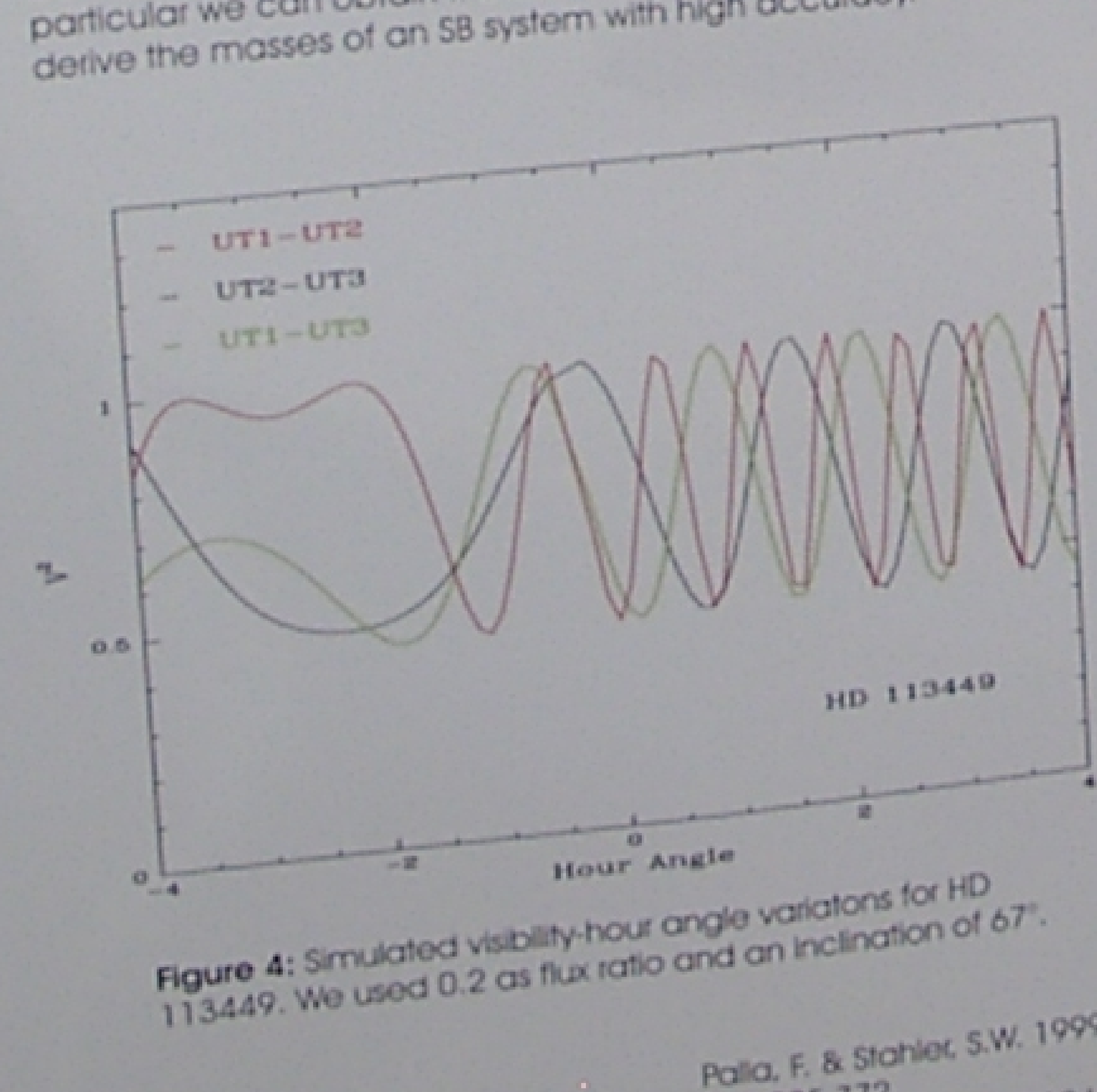

Figure 4: Simulated visibility-hour angle variatons for HD 113449. We used 0.2 as flux ratio and an inclination of 67°.

First observations of a PMS binary with the VLTI

In this ESO period (P79) the first of our object (HD 113449) is beening observed with AMBER. We asked for two observations separated by two months in the way that we can solve the visual orbit and we can determine the masses of the two components. In the meanwhile we developed a software that allows to calculate the squared visibility of a binary, given all the 7 parameters of the visual orbit, the wavelength of observation, the baseline and the date of observation.

We finally hope to measure the masses with an accuracy that is higher than 10%. Figure 4 shows the squared visibility of HD 113449 when observed on the 28th of May with three different VLTI baselines, at a wavelength of 2.4 μm. We put in the 5 paramters of the orbit that we already know from the spectroscopical observations (ie, a sin i, P, Tp, e) and some assumed values for the longitude of the abscendig node (Ω) and for the inclination (i) that can be only deduced with interferometry. For this calculation we also assume a flux ratio of 0.2 (G5 V the primary and early M the secondary).

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Email address: cusano@tls-tautenburg.de